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DEVELOPMENT OF A STANDARD BENDING TEST FOR ROPE YARNS

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ABSTRACT

In considering the properties of cordage the need for physical tests other than those for breaking strength was evident. Accordingly, a study of other methods of test which would more nearly simulate service conditions was undertaken. Apparatus to test the effect of bending a rope yarn was designed and built. The yarn under tension is bent over a cross arm a certain number of oscillations per minute. An auxiliary instrument was designed which would enable the transfer of the specimen from the rope or coil to the clamps of the apparatus without changing the original twist. The variables of the apparatus were studied and a method of test formulated.

CONTENTS

I. INTRODUCTION

Laboratory data to determine the working value of rope have been obtained usually only by tests for breaking strength. The conditions of this test, especially those governing the method of holding and the application of the load, are usually kept constant in any one laboratory, although they have been found to vary somewhat in different laboratories.[1] The present breaking strength tests do not indicate the effect of repeated stress or the complexity of strains incident to bending, both of which occur in actual service. In fact, it has been shown that ropes in service seldom break between the fastenings when subjected to a tensile stress.

The Government is a very large user of rope and makes its purchases on the basis of specifications [2] which were formulated in cooperation with cordage manufacturers.[3] The committee consid-

[1] Schoffstall, C. W., "Rope test methods studied," Cord Age, June, 1925.

[2] Federal Specifications Board Specification No. 61, Master Specification for Manila Rope.

[3] Members of the Cordage Institute, 350 Madison Avenue, New York, N. Y.

ering these specifications requested that the bureau make a study of this problem so that the service conditions might be more nearly simulated.

Preliminary consideration of the effect of bending showed the desirability of studying two phases of the problem—the effect of bending on rope and the effect of bending the unit structure of the rope, the rope yarn formed by twisting together the cordage fibers. The former study is being made but will require a lengthy period of time for completion. The study of the bending fatigue of the rope yarn offered some very desirable possibilities provided that a suitable apparatus could be designed and built. The most important of these features seemed to be the determination of a measure of quality of fiber.

The quality of the rope as affected by the grade of fiber has never been successfully determined. Chemical and microscopical tests have not been particularly valuable in this instance. In most cases the several kinds of hard fibers are only differentiated by chemical methods with difficulty. By these methods the detection of a difference in grade of a particular kind of fiber is hardly feasible. Microscopical analysis is very seriously affected by the experience and expertness of the operator, the "human equation" lessening the value and the usefulness of results for practical purposes. There is a need then for a fatigue test on either the rope or some unit of its structure which will measure differences resulting from using the different grades of fiber. In order possibly to obtain these useful data, it was thought desirable to design apparatus which would measure the effect of bending or otherwise fatiguing the rope yarn according to some method which would permit ease of operation and give reproducible results.

It was found that very little consideration had been given to this problem previously. One apparatus had been built [4] in the laboratory of one manufacturer to study the wearing qualities of rope yarn. A line drawing of this apparatus is shown in Figure 1. This apparatus consists of a cylindrical clamp (with the edges rounded off to prevent cutting of the yarn) oscillating vertically through an angle of 108°. Tension on the yarn was exerted by means of a weight sliding in a guide. A short spring was placed between the yarn specimen and the weight, and the total length of specimen and spring was regulated so that when the oscillatory upward stroke began the weight was lifted. The speed used was 480 complete oscillations per minute, which seemed rather fast, although the spring helped to take up the resultant shock of such a speed. A revolution counter was attached.

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[4] By E. W. Brewster, North Plymouth, Mass.

II. PURPOSE OF INVESTIGATION

The purpose of this investigation was (*a*) to design and build a rope-yarn testing machine which would be suitable for the study of

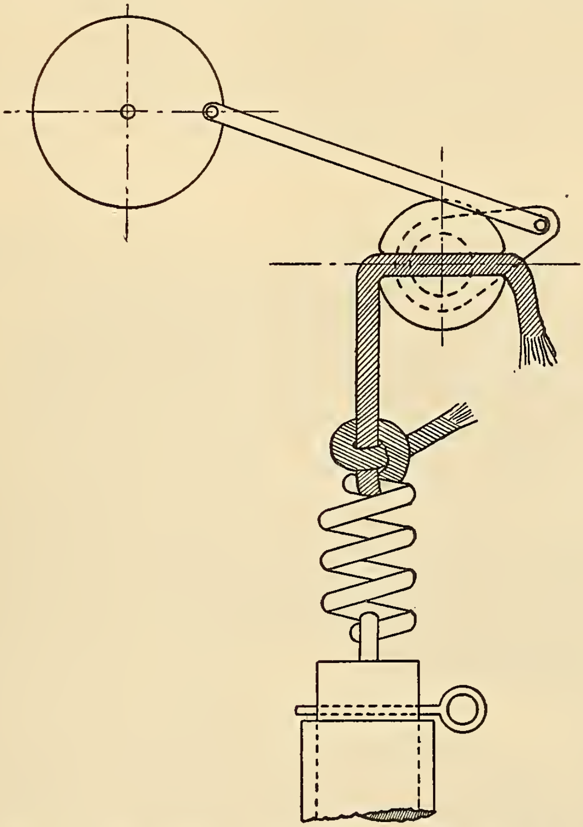

FIG. 1.—*Diagrammatic sketch showing principles of the Brewster rope-yarn bending apparatus*

the resistance of rope yarn to bending fatigue, (*b*) to standardize a method of test using this machine.

III. TESTING CONDITIONS

1. APPARATUS

It was decided to design the machine so that the yarn would be bent through a measured arc under a definite tension. This principle is illustrated diagrammatically in Figure 2.

Accordingly, there was built at this bureau the yarn-bending machine shown in Figure 3. In the construction the original principle of the Brewster apparatus, that of bending over a rounded edge, was retained. A description of the operation of this machine is as follows: Clamp *D* holding yarn *I* is oscillated through an

angle of 90°. The position of the clamp is adjustable by means of lock nut *A*. The bending edge is a steel wire *E*. Tension is exerted by means of weight *F*, which travels on guides *G* in order to prevent the untwisting of the yarn and insure vertical motion. When the yarn breaks, the weight strikes a bar *R*, which throws out the clutch *M* and stops the unit. There are five bending units. The whole is driven by a one-half horsepower motor through a gear reduction. The speed at the cross arm is 80 or 113 oscillations per minute, as regulated. By means of a series of switches wired in parallel the

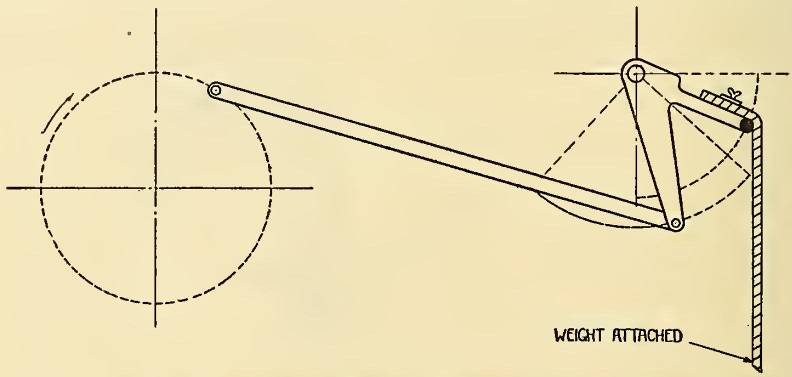

FIG. 2.—*Diagrammatic sketch of rope-yarn bending process*

motor is cut off when the last yarn is broken. A small pin *J* on the crank operates a counter which registers the number of oscillations required to break the yarn.

2. TEST SAMPLES

In the study of the variables of this machine a No. 18 manila yarn [5] was taken from a 3-inch (circumference) rope. This rope was made in accordance with and complied with United States Government Master Specification No. 61 for Manila Rope.

3. TWIST IN YARN PRESERVED

In order to preserve the original twist in the yarn while it was being transferred from the rope to the machine, a double clamp was devised, as shown in Figure 4.

4. HUMIDITY

The relative humidity readings were taken for several weeks and were found to vary between 30 and 80 per cent. Since a study of mean readings of the machine showed that no systematic variation occurred during this period, it was assumed that for the purpose of studying the variables of the machine itself the effect of humidity

[5] Rope yarn is sized by numbers, as No. 18s, No. 24s, etc. Number 18 means that 18 threads or yarns will make a strand ½ inch in diameter, a proper size strand used in making 3-strand, 3-inch circumference rope. It has been found that the number of the yarn multiplied by 15 will give the number of feet per pound; hence, a pound of yarn which is 270 feet long would be No. 18s yarn.

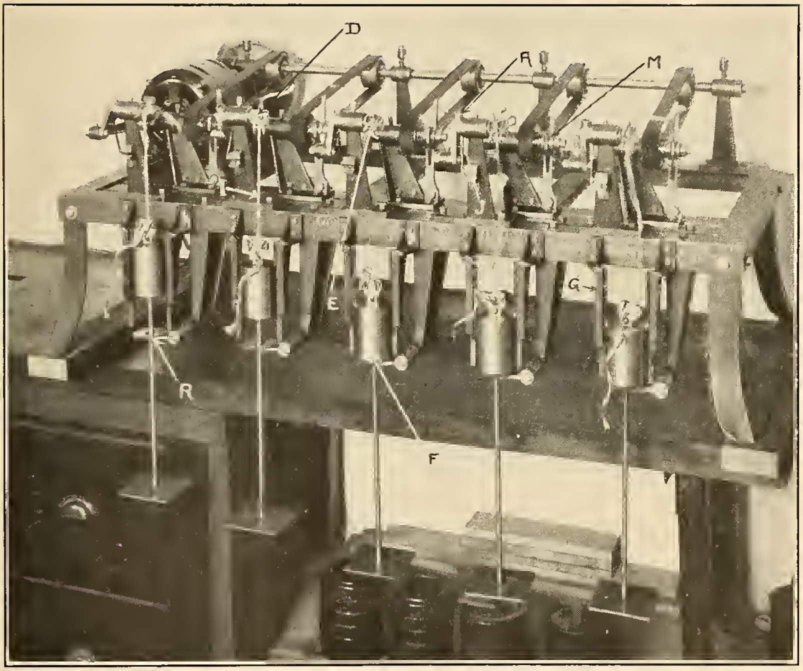

FIG. 3.—*The rope-yarn-bending machine built at the Bureau of Standards*

FIG. 4.—*Double clamp used to preserve the twist in the rope yarn in transferring it from the sample to the machine*

was not sufficient to warrant special apparatus. Further investigation may prove that humidity does affect the readings to a certain extent

The variables of the machine which were studied were position of cross arm, load, speed, and size of cross arm.

IV. PROCEDURE

To ascertain the most suitable angle of bending, three positions of the cross arm were arbitrarily chosen. These positions are designated by the angle which the cross arm makes with the vertical when at the highest point of its stroke. They were named for convenience: Position 1 for 90°, position 2 for 60°, and position 3 for 45°. The results obtained using each of these positions are shown in Figure 5, which also illustrates the arc through which the cross arm oscillates. The speed of the machine was fixed at 80 oscillations per minute, and the diameter of the cross arm was one-sixteenth inch during this phase of the work. The curves shown in Figure 5 were constructed as follows: It was found that if the results were plotted on logarithmic paper a straight line relation was obtained as shown in Figure 6, indicating a hyperbolic curve. All of the results were thus plotted, for this straight-line relation permits more satisfactory adjustment of experimental variations than the curved lines. The curves shown on Figure 5 were plotted from the straight-line relations, although for comparison the experimental results were plotted also.

In order to decide which of the three positions and what load should be applied in formulating a standard test procedure, the percentage probable error of an individual reading (approximate) was determined. For a given set of conditions the lower the per cent probable error the less the number of individual tests necessary to obtain the same degree of accuracy in the mean value. This percentage probable error (PE_{I}) was plotted against the various loads (in pounds) used as shown in Figure 7.

Considering the smooth curves shown in Figure 7, it is evident that for all three positions the loads between 16 and 19 pounds have the lowest per cent probable error of an individual reading. Another very valuable feature of these curves is that position 1 is markedly less critical than either of the others—that is, there is less tendency to approach a sharp bend in the lower portion of the curve. This least critical condition is desirable, for although in this study for convenience in interpretation of the data only one size of yarn was used, it is obvious that the greatest range of yarn size can be used without varying from a definite selected tension when the least critical condition occurs. This was a fortunate condition and enabled the selection of one tension for all sizes of yarn, yet permitting easy differentiation in the results.

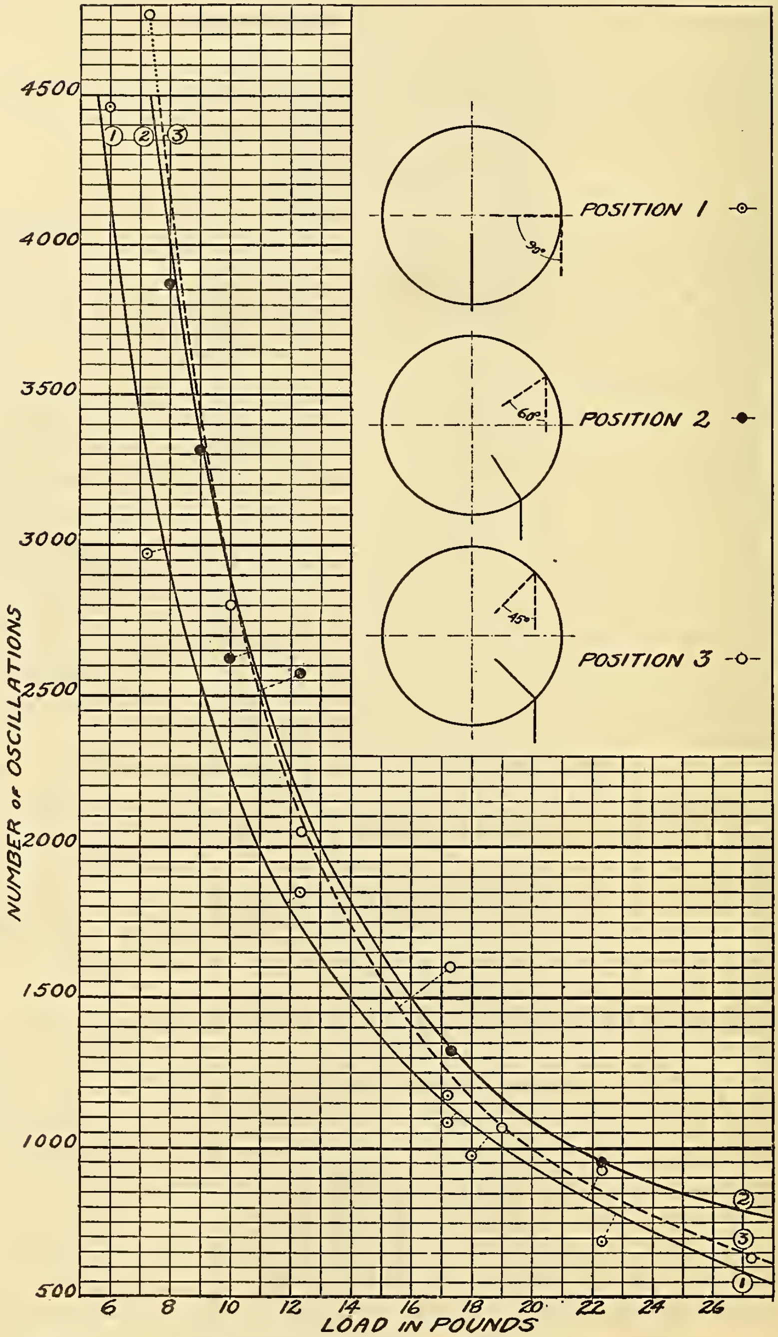

Fig. 5.—*Diagram of the three positions through which the cross arm operated, together with plot of results obtained with their use*

Having selected position 1, the results obtained using this position with different loads applied were plotted (results to the nearest 50 oscillations) on a distribution curve shown in Figure 8.

Figure 8 illustrates graphically the wide range resulting from using the smaller loads. As the load increases the range becomes smaller. However, when the load becomes large the liability of overstraining the specimen increases, as illustrated by some of the low readings shown in the grouping for the 22.3-pound load. The load of 18 pounds shows the most desirable grouping feature; that is, a small range of results. Referring back to Figure 7, it will be noted that the lowest point of the curve for position 1 occurs at (nearly)

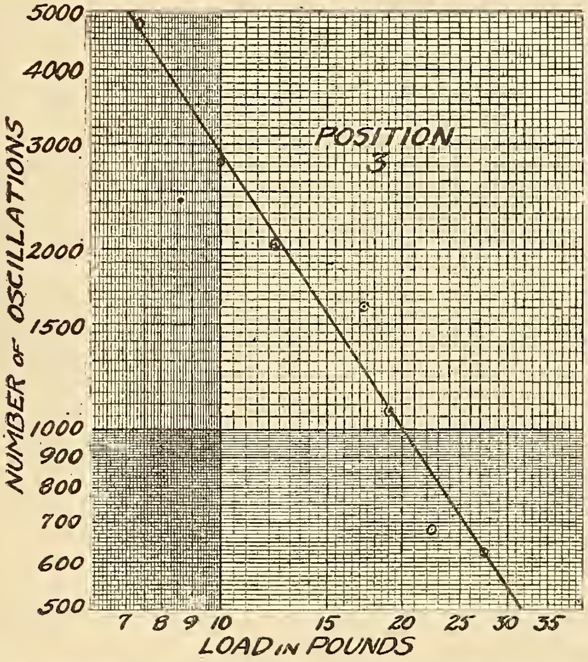

Fig. 6.—*Logarithmic plot of load and number of oscillations for position 3*

18 pounds. Accordingly, position 1, using a load of 18 pounds, was selected as standard for this test procedure.

In considering variations in speed it was found by using either 110 volts or 220 volts direct current the range in speed was sufficiently large, so that it was not considered desirable to effect other changes by using different gearings. Taking the lower speed as a basis, it was found that the higher speed permitted a time saving of 10 per cent. Since a large number of tests are frequently necessary to obtain a fair average, this saving in time becomes appreciable. Noticeable inaccuracies were not introduced by the higher speed, so the higher speed was selected for obtaining the data used in this standardization work.

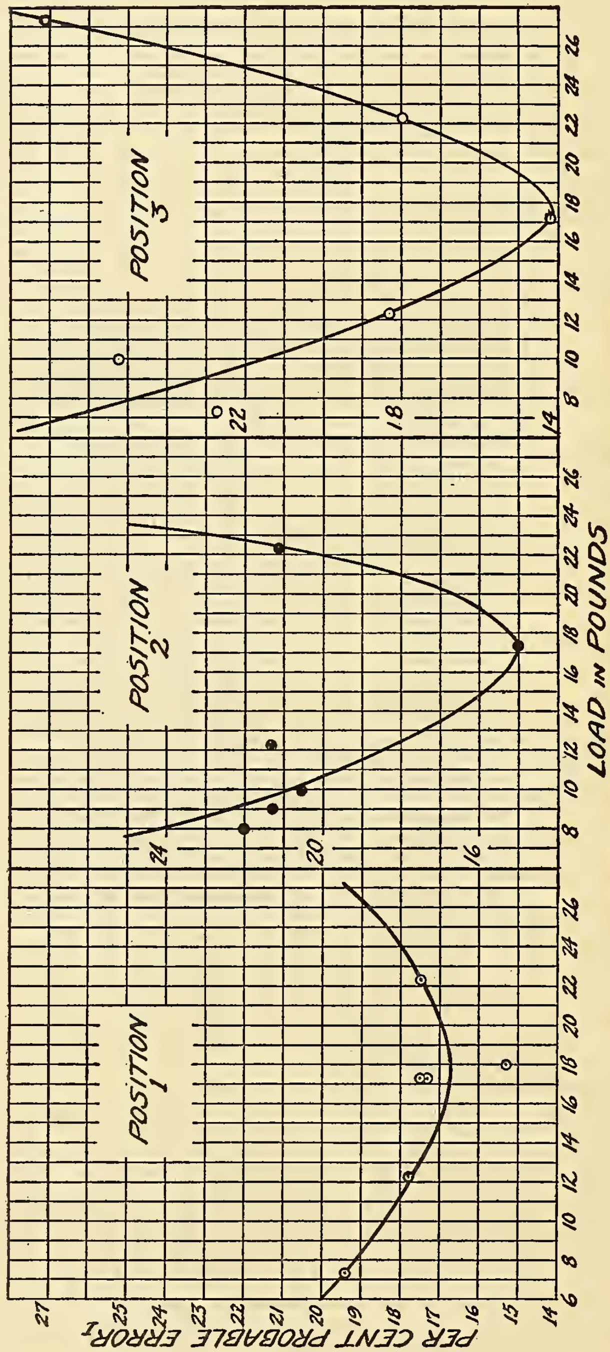

FIG. 7.—*Percentage probable error v. load in pounds for the three positions*

The selection of a suitable diameter of the cross arm offered very little difficulty. It was desired to use as small a diameter as possible, so that the tests could be run expeditiously. By trial it was found that wires less than one-sixteenth inch in diameter would not sustain the weight of 18 pounds without bending. The steel wire one-sixteenth inch in diameter proved satisfactory and was selected.

The variables having been studied so that a method of test on this apparatus could be formulated, some attention was given to determining how many tests would be necessary to obtain a fair average. The cost of making a test increases with the number of specimens necessary to obtain the average, both on account of the

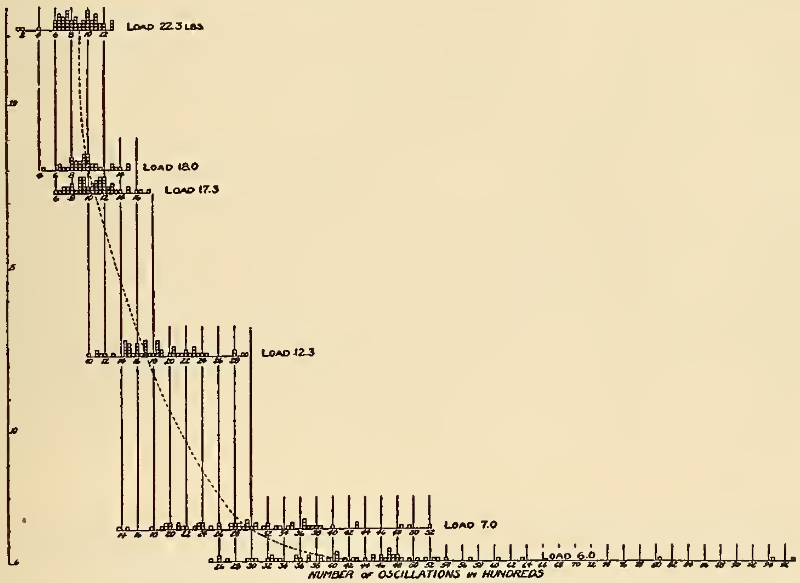

Fig. 8.—*Distribution curve for results obtained using different loads for position 1*

extra time involved and the additional materials required. It is desirable to eliminate any result which has been effected by faulty operation, but in material which is naturally as variable as rope yarn a large number of results are necessary to insure fairness, and some high and low results are to be expected. To obtain a degree of accuracy of approximately 5 per cent, it is necessary to average at least 30 results. Investigative work may require as high as 50 results. It has been found advantageous to graph the results in frequency charts, such as those shown on Figure 8. This facilitates interpretation by showing at a glance the range and the point at which most results fall. These features are frequently more valuable than the average in investigative work.

V. SUMMARY AND CONCLUSIONS

Apparatus was designed and built suitable for studying the bending fatigue of a rope yarn. An effort was made to accomplish this in its simplest form, so that it might be easily and cheaply reproduced in the mill and so that the results would be a measurement of a single characteristic. These features are desirable for the proper interpretation and correlation of test data from the several sources. From the interest shown by various manufacturers it is believed that this apparatus will be accepted and used in the cordage mills.

In the apparatus [6] built a rope yarn is bent over a cross arm at a certain number of oscillations per minute. To one end of the yarn a weight is attached which slides in a guide, so that the twist of the yarn is retained. An auxiliary instrument which preserved the original twist was constructed to be used in transferring the specimen from the rope or coil to the apparatus.

From a study of the variables of testing using this apparatus the following test procedure is recommended: The angle of bending should be that in which the cross arm makes a 90° angle with the vertical when at the highest point of its stroke. The cross arm should be oscillated through 90° at the rate of 110 (plus or minus 5) oscillations per minute. The cross arm should be of one-sixteenth inch steel wire. An auxiliary instrument which will preserve the original twist should be used in transferring the specimen from the rope or coil to the clamps of the apparatus. An average of at least 30 specimens should be used to obtain a result if an accuracy of 5 per cent is desired.

WASHINGTON, April 24, 1925.

[6] Blue prints of the apparatus built and in use at the Bureau of Standards will be loaned upon request addressed attention of "textile section."